MODIS Semi-annual Report (July 2000 – December 2000)

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(This reports covers the MODIS **cirrus characterization and correction** algorithm and part of the MODIS **near-IR water vapor algorithm**)

Main topics addressed in this time period:

1. **MODIS near-IR water vapor algorithm**:

The near-IR water vapor algorithm is working well in the MODIS operational computing environment. We can make routine process of all L1B data to produce L2 MOD05 near-IR water vapor products. We can also produce the daily L3 near-IR water vapor products on a global scale.

In June of 2000, we found a problem with our near-IR water vapor codes. The QA parameters written into the MOD05 HDF files were not correct. It took us quite a bit of time and efforts to identify the problem and to fix the problem. A newer version of the near-IR water vapor algorithm was delivered to MODIS Project in July, 2000. With the proper implementation of QA-related routines in our L2 algorithm, the L3 daily and global near-IR water vapor images over clear land surfaces and water surfaces with sun glint were produced correctly using the MODIS Atmosphere Group's L3 algorithm.

We made extensive analysis of L2 near-IR water vapor products. Spatial variations of water vapor values in our L2 near-IR water vapor image are quite realistic. Water vapor values decrease rapidly with increasing surface elevation. Water vapor values over the land-ocean boundary areas are generally greater than over interior land areas. Large-scale water vapor variations and transports associated with weather front systems can be observed.

We compared near-IR water vapor products with IR water vapor products derived with an algorithm developed at University of Wisconsin. The near-IR water vapor channels are more sensitive to water vapor variations than IR emission channels. The near-IR algorithm allows retrievals of water vapor values over desert areas, while the IR algorithm often fails (due to variations of surface emissivity with wavelength in IR spectral regions).

Sample results from our near-IR water vapor algorithm were reported during MODIS Science Team meetings, and can be found from the MODIS web page at: http://modarch.gsfc.nasa.gov/MODIS

We made preliminary validation on the MODIS near-IR water vapor products by comparing our retrieved water vapor values with those derived from ground-based upward-looking sun-photometer measurements. Richard Ferrare at NASA Langley Research Center compared water vapor measurements obtained from ground-based lidar and microwave radiometer with near-IR water vapor values derived from MODIS data over a DOE ARMS experimental site in Oklahoma. We found that the near-IR water vapor values derived from MODIS data are typically 20 to 30% greater than surface-based measurements. The differences are largely due to errors in water vapor line parameters compiled in the HITRAN96 database. More recent measurements of near-IR water vapor line parameters conducted in Britain have demonstrated that the integrated band intensity for all the lines in the 0.94-micron water vapor band and compiled in the HITRAN96 database should be increased by approximately 21%. The water vapor line parameters from the recent measurements are not publicly available yet.

In view of the situation on water vapor line parameters, we decided to update the lookup tables used in our algorithm by including the so called "water vapor continuum absorption" effects during the generation of the updated lookup tables. With the updated lookup tables, our derived water vapor values from MODIS near-IR channels should be reduced by 10 to 25% depending on how much water vapor in the atmosphere. The introduction of water vapor continuum absorption in the calculation water vapor transmittances, using for examples the LOWTRAN7 and MODTRAN codes, has no scientific basis. The updated version of the algorithm was operating since November of 2000.

In the near future when the newer water vapor line parameters are available, we will update the lookup tables again and remove the controversial "continuum absorption" in our calculations of water vapor transmittances.

2. **MODIS thin cirrus reflectance and contrail algorithms**:

The at-launch version of the MODIS thin cirrus reflectance algorithm still works reasonably well. We are producing L2 thin cirrus reflectance products for each MODIS granules and L3 daily and global cirrus reflectance products. In this version of the algorithm, the two-way water vapor transmittance on the Sun-cirrus-MODIS path was estimated based on our previous experiences gained from analysis of hyperspectral imaging data acquired with the NASA

JPL AVIRIS instrument (Airborne Visible Infrared Imaging Spectrometer). At present, we often slightly under-estimate the cirrus reflectances in the visible.

Progress has been made with deriving the 2-way water vapor transmittance on the Sun-cirrus-MODIS path from the scatter plot between the 1.38-micron channel image and the 0.65-micron channel image. We are currently testing an algorithm with various MODIS data cubes acquired over different geographical regions. In this algorithm, one large MODIS image is devided into 9 smaller images. The division is necessary because cirrus clouds over a large area of 2300 km by 2000 km are usually not at the same height level. A scatter plot between the 1.38-micron channel and 0.66-micron channel is made for each of the sub-images. From each scatter plot, 2-way (Sun-cirrus-sensor) water vapor transmittances for each sub-area are estimated. To avoid any artificial discontinuity for the cirrus reflectances, a 2-D interpolation scheme is employed.

Traditionally, the detection of polar clouds over bright snow surfaces was very difficult from data acquired with meteorological satellites (such as those of the AVHRR series). Through analysis of MODIS data, we have found that such clouds can be easily detected from the MODIS 1.375-micron images. The reasons are that, at 1.375 micron, the snow and ice-covered surfaces are quite dark due to large particle sizes and strong ice absorption. The particles in cirrus clouds and water clouds in the polar region are much smaller than snow and ice particles on the surfaces. The solar radiation at 1.375-micron scattered by clouds can be detected by the MODIS sensor. As a result, the 1.375-micron channel detects clouds over dark surfaces in the polar region. We feel that the MODIS data will greatly improve our ability in remote sensing of polar clouds. A significantly improved polar cloud climatology can be obtained from MODIS data in comparison with the ISCCP polar cloud climatology.

Through analysis of MODIS 1.38-micron images, we found that aircraft-emission induced contrail cirrus clouds can be observed using this channel. If airplanes were not flown from the areas, the cirrus clouds might be absent. Therefore, aircraft-induced contrail cirrus may have some climatic effects regionally.

Our L3 global daily cirrus reflectance images show very well the centers of convective clouds. The peak positions of these clouds have seasonal variations.

Sample results from our thin cirrus algorithm were reported during MODIS Science Team meetings, and can be found from the MODIS web page at: http://modarch.gsfc.nasa.gov/MODIS

3. **Visualization**

In order to view MODIS L1B, L2, and L3 imaging data stored in HDF files, we made additional code development using IDL. We wrote IDL routines to produce nice-looking L2 and L3 water vapor and cirrus reflectance images. We wrote F90 routines to read individual QA parameters (in one bit or more than one bit) packed inside a byte array.

4. **Radiative Transfer Modeling**:

Ping Yang has always been studying the scattering properties of cirrus particles. He participated the development and validation of the ice library used in MODIS PGE06 for the retrieval of optical thickness and effect size for ice clouds. He has updated the definition of the effective size in the library. In the radiative transfer calculation for generating the ice library, he also developed an algorithm to truncated the forward delta-peak in the phase functions that were previously generated for the MODIS team.

Ping Yang also conducted some fundamental research regarding the infrared spectral information for the scattering properties of cirrus clouds. In particular, he developed a database for the single-scattering parameters of ice crystals in 8-13 μm spectral region. This database will be useful for the retrieval of cirrus optical properties on the bases of MODIS infrared bands such as bands 29, 31, and 32.

5. **Meetings**

Gao, B.-C., attended the AGU Fall Conference held in San Francisco held during December 14 - 19, 2000.

Yang, P., attended the fifth international conference on light scattering by nonspherical particles, August 28-September 1, 2000. Halifax, Canada

Gao, B.-C., attended SPIE's the 2nd International Asia-Pacific Symposium on Remote Sensing of the Atmosphere, Environment, and Space held in Sendai, Japan during 9-12 October 2000.

Gao, B.-C., attended the IEEE 2000 International Geoscience and Remote Sensing Symposium held in Hawaii USA during 24-28 July 2000.

6. **Publications**

Gao, B.-C., R.-R. Li, Quantitative improvement in the estimates of NDVI values from remotely sensed data by correcting thin cirrus scattering effects, Remote Sens. Env., 74, 494-502, 2000.

Yang, P., K. N. Liou, M. I. Mishchenko, and B.-C. Gao, 2000: An efficient finite-difference time domain scheme for light scattering by dielectric particles: application to aerosols, *Appl. Opt*., 39, 3727-3737.

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Hu, Y.-X., D. Winker, P. Yang, B. A. Baum, L. Poole, and L. Vann, 2000: Identification of cloud phase from PICASSO-CENA lidar depolarization: A multiple scattering sensitivity study, In press, *JQSRT*.

Nasiri, S. L., B. A. Baum, A. J. Heymsfield, P. Yang, D. P. Kratz, Y.-X. Hu, 2000: The development of Midlatitude Cirrus Models for MODIS using FIRE-I, FIRE-II, and ARM in-situ data (submitted).

Baran, A. J., P. Yang, and S. Havemann, 2000: Calculation of the single-scattering properties of randomly oriented hexagonal ice columns: A comparison between the exact T-matrix theory and the finite-difference time-domian method. Appl. Opt. (submitted).